~~~~~~~~~~~~~~C llulos ~~~~~~~~~~~~~~

CAS Reg. No.:
[redacted]
Molecular Formula:
$(C6H10O5)_n$
Fragment:
C6H10O5
General Info:
Overview of Cellulose - sources and properties.
Cellulose is a polysaccharide polymer, containing a linear array of anhydroglucose units that are assembled into complex multi-stranded fibres and films. The polymer is the major structural component of plant cell walls and is particularly important in cells that form stems and wood. It is also the major constit. of fibres such as cotton, flax, jute, hemp and ramie. Certain green algae and bacteria also produce the polymer. Chemical processing can rearrange the macromolecular struct. of the polymer, producing fibres such as rayon.
The struct. and props. of cellulose can be described at several levels
The single polymer chain.
The arrays of multiple overlapping chains of the polymer that make elementary fibrils and microfibrils, the basic building blocks found in natural cellulose-containing structs.
Assemblies of microfibrils that combine to make fibrils, the intermediate building blocks in construction of components of plants, such as the framework for cell walls, the skeletons of complex structs. such as stems, wood etc. and valuable fibres such as cotton.
Reconstituted fibres produced commercially by re-precipitating cellulose polymer chains after solubilisation as salts of derivs.

~~~~~~~~~~~~~~Cellulose~~~~~~~~~~~~~~

Synonym:
Natural cellulose
α-Cellulose
Cellulon
Monomers: Related Polymers:
Cellulose II
Cellulose
Material Class
Polysaccharides
Polymer Type:
cellulosics
CAS Reg. No.:
[redacted]
Molecular Formula:
$(C6H10O5)_n$
Fragment:
C6H10O5
Base monomer unit glucose **Mol. Weight:**
MW 331100 (cotton), 366100 (softwood), 339700 (hardwood). DP (of crystalline regions): 200-250 (purified cotton), 300-350 (ramie), 250-400 (unbleached sulfite wood pulp), 2000 (cotton). DP of whole fibres: 2000-14000 (cotton fibre), 9550 (bast fibres), 26500 (*Valonia*), 2000-3700 (*A. xylinium*), 8200-8450 (wood)
Additives:
Flame retardants
Morphology:
Degree of crystallinity: cotton 82-87% (acid hydrol.), 70% (X-ray), 60% (density), 60% (deuterium exchange), 72% (formylation); Ramie 95% (acid hydrol.), 70% (X-ray), 60% (density); wood pulp 65% (X-ray), 65% (density), 45-50% (deuterium exchange), 53-65% (formylation).

A struct. based on a modified two-phase (crystalline-amorph.) model has been reported [27]
Gen ral Info:
Two different forms of crystalline Cellulose I named 1α and 1β have been recognised recently. The 1α form can be converted to 1β at high temps. in alkali. The 1β form is thought to predominate in most fibre and wood celluloses of commercial importance. Main component of higher plant cell walls. Also found in some bacteria, algae, fungi and tamicates. Secondary cell walls of fibres such as cotton are >90% cellulose, while in bast fibres it is *ca.*. 70% and in woods the content is *ca.* 40-50%. Cellulose is the most abundant, continually synthesised chemical on earth, wth *ca.* 8×10^{10} *t/yr produced and degraded. Pulping and processing gives the rearranged polymer, Cellulose II (Cellulose II). Crystalline average length: 144 nm (cotton), 120 nm (ramie), 153 nm (wood); width: 50 nm (cotton), 35 nm (ramie), 37 nm (wood); thickness 64 nm (cotton), 40 nm (ramie), 45 nm (wood)*

Ethylcellulose

Synonym:
Perethylcellulose
Monomers:
Base monomer unit glucose
Related Polymers:
Cellulose II
Material Class
Polysaccharides
Polymer Type:
cellulosics
CAS Reg. No.:
[redacted]
General Info:
Approx 2.3 ethyl groups per monomer for films; 2.4-25 for lacquer.

C llulose I

Synonym:
Natural cellulose
α-Cellulose
Cellulon

Monomers:
Base monomer unit glucose

Related Polymers:
Cellulose II
Cellulose

Material Class
Polysaccharides

Polymer Type:
cellulosics

CAS Reg. No.:
[redacted]

Molecular Formula:
$(C6H10O5)_n$

Fragment:
C6H10O5

Mol. Weight:
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Additives:
Flame retardants

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Volumetric and Calorimetric Properties

Density:

No.	Value	Note
1	1.482 – 1.489 g/cm³	amorph. x-ray detn. [1]
2	1.535 – 1.547 g/cm³	wood pulps [11,22]
3	1.545 – 1.585 g/cm³	cotton [11]
4	1.55 g/cm³	ramie [11]
5	1.582 – 1.63 g/cm³	[11]
6	1.59 – 1.63 g/cm³	crystalline, x-ray detn.

Thermodynamic Props General:

Heat of combustion 17.43 kJ kg^{-1} K^{-1} (cotton) [1,4]. Heat of crystallisation 121.8 kJ kg^{-1} [11]

Thermal Conductivity:

No.	Value	Note
1	0.029 – 0.17 W/m K	papers, various [11]
2	0.071 W/m K	cotton, density 0.5 g cm^{-1} [11]

Specific Heat Capacity:

No.	Value	Note
1	1.214 – 1.357 kJ/(kg °C) [P]	cotton [4]
2	1.327 – 1.353 kJ/(kg °C) [P]	hemp [4]
3	1.365 kJ/(kg °C) [P]	ramie [4]

Glass Transition Temperature:

No.	Value	Note
1	220 – 245°C	[11]
2	243 – 433°C	[11]

Transition Temperatures:

No.	Value	Note
1	19 – 23°C	Secondary transition temp. [13]
2	>290°C	min. Ignition temp. [1]
3	475°C	Cotton [4]

Surface Properties and Solubility

Solvents/Nonsolvents:

Sol. DMF, chloral, pyridine, [7], conc. mineral acids (with degradation) [1], inorganic salts (e.g. $ZnCl_2$, LiCl, $Ca(SCN)_2$), strong alkalis, metal complexes (e.g. $[Cu(NH_3)_4](OH)_2$ (Cuoxam), $[Cd(en)_3](OH)_2$, (Cadoxen)) [11]. Swollen by: liq. NH_3, hydrazine [11]. Liq. cryst. with N-methylmorpholine-N-oxide [15]

Surface Tension:

No.	Value	Note
1	36 – 42 mN/m	20°, wood pulp [17]

2	42 mN/m	20% cotton [17]

Transport Properties

Water Absorption:

No.	Value	Note
1	0.6 – 11.7%	amorph. cellulose, 11-97% relative humidity [16]
2	7 – 8%	cotton [16]
3	8 – 14%	cellulose, 20°, 60% relative humidity [21]

Mechanical Properties

Mechanical Properties General:
Moduli of rigidity have been reported [6]

Tensile Strength at Break:

No.	Value	Note
1	200 – 800 MPa [6-13% extension]	wet, cotton [1]
2	200 – 800 MPa [12-16% extension]	dry, cotton [1]
3	824 MPa [1.8% extension]	dry, flax [1]
4	863 MPa [2.2% extension]	wet, flax [1]
5	900 MPa [(2.3%)]	dry, ramie [1]
6	1060 MPa [2.4% extension]	wet, ramie [1]

Elastic Moduli:

No.	Value	Note
1	48 – 69 MPa	ramie [1]
2	59 – 78 MPa	hemp
3	78 – 108 MPa	flax [1]

Electrical Properties

Electrical Properties General:
Insulating value 500 kV cm^{-1} [10]

Strong Field Phenomena General:
Zeta potential 21.1mV (cotton), 18mV (unbleached sulfite pulp, water), 9mV (unbleached sulfite pulp, 20°, water) [11]

Dielectric Strength:

No.	Value	Note
1	7.7 – 9.2 kV/mm	50Hz, insulating paper [11]
2	30 – 50 kV/mm	50Hz, cellophane [4]
3	50 kV/mm	Native cellulose fibre [11]

Dielectric/Permittivity Constant:

No.	Value	Note
1	1.67 [10 kHz]	25°, cotton linters [4]

2	2.2 – 2.3	pulp sheets [1]
3	2.42 [10 MHz]	25°, cotton cellulose [4
4	2.86 [200 kHz]	25°, cotton cellulose [4
5	5.7	crystalline portions [1]

Dissipation Factor:

No.	Value	Note
1	0.02 [1 kHz]	20° [11]
2	0.07 [100 MHz]	20° [11]

Optical Properties

Refractive Index:

No.	Value	Note
1	1.525 – 1.534	perpendicular, ramie [11,14]
2	1.527 – 1.534	perpendicular, cotton [11,14]
3	1.544	perpendicular to fibre axis cellulose I [11]
4	1.576 – 1.595	parallel, cotton [11,14]
5	1.595 – 1.601	parallel, ramie
6	1.618	parallel to fibre axis, cellulose I [11]

Stability

Polymer Stability General:

Thermal Stability General:
Decomposition temp. 200-270° [11], 150° (cotton) [12]

Decomposition Details:
Decomposes at 250-397° giving H_2O, CO_2, CO and tar. Major tar component is laevoglucosan [9]

Flammability:
Fl. p. 361° (cotton) [4]. Limiting Oxygen Index 18.4 % [11]. Mechanism of pyrolysis and the use of flame retardants have been reported [28]

Biological Stability:
Degraded by cellulases prod. by bacteria such as Trichoderma sp.

Hydrolytic Stability:
Susceptible to acid hydrol., with amorph. regions reacting faster than crystalline sections. In alkali the polymer dissolves at elevated temps. undergoing depolymerisation by β-elimination of H_2O

Applications/Commercial Products

Applications:
Wide range of uses from cloth to paper, yarn to insulation, and, in the form of wood, as fuel and structural materials

Tradenames:

Tradenames		
Grade	Manufacturer/Supplier	
Cellulon	Bacterial cellulose	Weyerhauses
Cotton		
Hemp		
Ramie		

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Ethylcellulose

Synonym:
Perethylcellulose

Monomers:
Base monomer unit glucose

Related Polymers:
Cellulose II

Material Class
Polysaccharides

Polymer Type:
cellulosics

CAS Reg. No.:
9004-57-3

General Info:
Approx 2.3 ethyl groups per monomer for films; 2.4-25 for lacquer.

Volumetric and Calorimetric Properties

Density:

No.	Value	Note
1	1.09 – 1.17 g/cm³	[6]
2	1.14 g/cm³	[1,3]

Thermal Expansion Coefficient:

No.	Value	Note
1	0.0001 – 0.0002 K^{-1} [L]	[6]

Thermal Conductivity:

No.	Value	Note
1	0.16 – 0.3 W/m K	[6]

Melting Temperature:

No.	Value	Note
1	135°C	crystalline [6]

Glass Transition Temperature:

No.	Value	Note
1	316°C	[11,13]

Deflection Temperatures:

No.	Value	Note
1	45 – 88°C	1.82 MPa [6]

Vicat Softening Point:

No.	Value	Note
1	152 – 162°C	[1,3]

Surface Properties and Solubility

Solubility Properties General:
Solubility 4-8% NaOH 0.5-0.7 [4]. Cold water 0.8-1.3 [4]. Organic solvents 2.3-2.6 [4]

Solvents/Nonsolvents:
Liq. crystals sol. $CHCl_3$ [9], dioxan [11], AcOH [10], DMSO [8]

Surface Tension:

No.	Value	Note
1	32 mN/m	20° [11,12]

Transport Properties

Polymer Solutions Dilute:
Intrinsic viscosity 11.0 dl g^{m1} (MW 625000, DP 2650); 7.75 dl g^{-1} (MW 335000, DP 1420); 3.95 dl g^{-1} (MW 190000, DP 805) [5]

Water Absorption:

No.	Value	Note
1	0.8 – 1.8%	24h [6]
2	2%	[1]

Gas Permeability:

No.	Value	Note
1	0.06675 cm^3/m^2 atm day [H_2O]	890 g m^{-2} day^{-1}, 75 µm film, ASTM E96-66 [1]
2	1740 cm^3/m^2 atm day [O_2]	$26.5 \cdot 10^{-10}$, 30°
3	2692 cm^3/m^2 atm day [CO_2]	$41.0 \cdot 10^{-10}$ cm^2 $(s\ cmHg)^{-1}$, 30°
4	5516 cm^3/m^2 atm day [N_2]	$84 \cdot 10^{-10}$, 30°
5	5713 cm^3/m^2 atm day [H_2]	$87 \cdot 10^{-10}$ cm^2 $(s\ cmHg)^{-1}$, 20°
6	13396 cm^3/m^2 atm day [SO_2]	$204 \cdot 10^{-10}$ cm^2 $(s\ cmHg)^{-1}$
7	26266 cm^3/m^2 atm day [He]	$400 \cdot 10^{-10}$ cm^2 $(s\ cmHg)^{-1}$, 30°
8	27580 cm^3/m^2 atm day [Ethylene oxide]	$420 \cdot 10^{-10}$ cm^2 $(s\ cmHg)^{-1}$, 0°
9	46294 cm^3/m^2 atm day [NH_3]	$705 \cdot 10^{-10}$ cm^2 $(s\ cmHg)^{-1}$ [6]
10	787992 cm^3/m^2 atm day [H_2O]	$12000 \cdot 10^{-10}$ cm^2 $(s\ cmHg)^{-1}$, 20°

Mechanical Properties

Tensile Strength at Break:

No.	Value	Note
1	46 – 72 MPa	dry, 75 µm film [2

Mechanical Properties Miscellaneous:

Wet tensile strength is 80-85% of dry film value [1,3]. Flexibility, folding endurance 160-2000 (dry, 75 µm film) [1,3]

Hardness:
Sward 52-61 (75 µm film) [1,3]. Rockwell R50-R115 [6]

Izod:

No.	Value	Note
1	21 J/m	[No] 23° [6]

Electrical Properties

Volume Resistivity:

No.	Value	Note
1	0.001 – 0.1 10^{15} ohm cm	[1,3]

Dielectric Strength:

No.	Value	Note
1	13.8 – 19.7 kV/mm	[6]
2	600 kV/mm	1500 V in^{-1}, ASTM D149-64 [1,3]

Dielectric/Permittivity Constant:

No.	Value	Note
1	2.5 – 4 [60 Hz]	25° [1,3]
2	2.8 – 3.9 [1 MHz]	25° [1,3]
3	3 – 4.1 [1 kHz]	25° [1,3]

Dissipation Factor:

No.	Value	Note
1	0.002 – 0.02 [1 kHz]	25° [1,3]
2	0.005 – 0.02 [60 Hz]	25° [1,3]

Optical Properties

Refractive Index:

No.	Value	Note
1	1.47	cast film [2]

Volume Properties/Surface Properties:
Light transmission at 310-400 nm is practically complete [1,3] and at 280-310 nm it is <50% complete [1,3]. Discoloration by sunlight is very slight [1,3]

Stability

Polymer Stability General:

Decomposition Details:
Decomposes at 306°. Products mainly gases; other products include acetaldehyde, aliphatic

comp unds and furans

Applications/Commercial Products

Proc/Manuf Routes:
Reaction of alkali cellulose with ethyl chloride at high pressure and temp.

Applications:
Lacquers and varnishes, printing inks and adhesives. Also used in food and food packaging applications

Tradenames:

Tradenames	
Grade	Manufacturer/Supplier
	Aqualon
	Dow

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